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PATENT & TRADEMARK OFFICE

#15 Brief 4/19/01

U.S. Express Mail No. : EF275413071US
Attorney Docket No. : AM-1776
Serial No. : 08/995,108

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of: Peijun Ding et al.	§ Att'y Ref. No: AM-1776
	§
Serial No.: 08/995,108	§ Filed: December 19, 1997
	§
Group Art Unit: 1745	§ Examiner: J. Mercado
	§
Title: A TAILORED BARRIER LAYER	§
WHICH PROVIDES IMPROVED	§ Mailing Address:
COPPER INTERCONNECT	§ Patent Counsel
ELECTROMIGRATION RESISTANCE	§ Applied Materials, Inc.
	§ P.O. Box 450-A
	§ Santa Clara, CA 95052

Date: April 13, 2001

APPELLANTS' REPLY TO EXAMINER'S ANSWER UNDER 37 C.F.R. 1.193 (b)

BEFORE THE BOARD OF PATENT APPEALS AND INTERFERENCES

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Hon. Assistant Commissioner For Patents
Washington, DC 20231

Sir:

This is appellants' Reply in response to the Examiner's Answer mailed February 13, 2001. The required response period is two months from the date

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CERTIFICATE OF MAILING UNDER 37 CFR 1.10

I hereby certify that this paper and any documents said to accompany this paper are being deposited with the U.S. Postal Service on the date shown below with sufficient postage as U.S. EXPRESS MAIL NO. EF275413071US in an envelope addressed to the: Assistant Commissioner for Patents, Box AF, Washington D.C. 20231.

Shirley L. Church

Date: April 13, 2001 Shirley L. Church, Reg. No.31,858

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of the Examiner's Answer, and applicants' Reply is being filed within that time limit.

Applicants are providing this Reply to address three new issues raised by the Examiner in his Answer.

The First New Issue is a general one:

WHETHER ARGUMENTS RELATED TO ELECTROMIGRATION ARE NOT PERSUASIVE, BECAUSE A LIMITATION RELATED TO ELECTROMIGRATION IS OUTSIDE THE SCOPE OF THE CLAIMS

In the Examiner's Answer, "Response to Argument":

Re Issue 1: The rejection of Claims 8 - 17 under 35 U.S.C. §103(a) as being unpatentable over Gelatos et al. in view of Landers et al., and in particular with respect to applicants' Group 1, Claims 8 - 12, 14/8, 14/12 and 15 - 17, at Page 10, lines 12 and 13, the Examiner answers that arguments directed to the fact that Hoshino does not address electromigration are not persuasive, as these limitations are outside the scope of the present claims.

With respect to applicants' Group 2, Claims 13 and 14/13, at Page 11, lines 11 - 12, the Examiner answers that arguments directed to the fact that Hoshino does not address electromigration are not persuasive, as these limitations are outside the scope of the present claims.

Re Issue 2: The rejection of Claims 8 - 17 and 21 - 26 under 35 U.S.C. §103 as being unpatentable over Hoshino in view of Landers, and in particular with respect to applicants' Group 4, Claims 21 and 22, at Page 13, lines 18 - 19, the Examiner answers that the arguments directed to Landers et al. not

mentioning electromigration are not persuasive, as this limitation is outside of the present claims.

Re Issue 4: The rejection of Claims 18 - 20 and 27 under 35 U.S.C. § 103(a) as being unpatentable over Hoshino in view of Landers et al. and further in view of Ngan et al., and in particular with respect to applicants' Group 6, Claim 27, the Examiner argues that arguments directed to the amount of electromigration is not persuasive as this limitation is outside the scope of the present claims.

The Title of applicants' application is: "A Tailored Barrier Layer Which Provides Improved Copper Interconnect Electromigration Resistance". Applicants' Appeal Brief, citing various locations within their application Specification, shows that a particular barrier layer structure is required to enable the formation of an overlying copper layer having the <111> crystallographic content necessary to provide highly desirable copper electromigration characteristics.

Applicants have taught one skilled in the art that a copper deposition having a particular <111> crystallographic content provides improved electromigration resistance, and that deposition of a conductive layer, preferably copper, over the combined barrier layer and wetting layer structure of the invention enables deposition of an overlying copper layer having the desired <111> crystallographic content. Applicants then claim the combined barrier layer and wetting layer structure. Applicants believe the Examiner is in error in stating that applicants' arguments to the fact that

none of the other art even mentions electromigration is not persuasive because the scope of the claims does not include the limitation necessary to provide a copper layer having the desired electromigration resistance.

Applicants' claims are to a method of producing combination barrier layer and wetting layer structures which produce a particular crystalline structure in a conductive layer (preferably copper) deposited over the combination structure. Since the crystalline structure provides improved electromigration resistance in the conductive layer, the improved electromigration resistance in the conductive layer is inherently claimed when the combination barrier layer and wetting layer structure is claimed.

Addressing each of the Examiner's statements in order:

Re Group 1: Claim 8 pertains to a method where a layer of TaN_x is deposited over a particular thickness range; then a layer of Ta is deposited over a particular thickness range; then a conductive layer is deposited over the Ta layer, where the substrate temperature during deposition of the conductive layer, and in subsequent processing steps is less than about 500 °C. A copper layer produced by the method (which provides a TaN_x /Ta/ Cu structure) has been shown by applicants to exhibit the desired <111> content which provides an improvement in electromigration resistance.

In applicants' Summary of the Invention at Page 5, lines 12 - 19, applicants state: "We have discovered that tantalum nitride (TaN_x) is a better barrier layer for copper than tantalum (Ta). However, copper deposited directly over TaN_x does not exhibit a sufficiently high degree of <111> crystal

orientation to provide the desired copper electromigration characteristics. We have developed a barrier layer structure comprising a layer of Ta overlying a layer of TaN_x which provides both a barrier to the diffusion of a copper layer deposited thereover, and enables the formation of a copper layer having a high <111> crystallographic content, so that the copper electromigration resistance is increased." At lines 23 - 24: "For a typical interconnect, the TaNx layer thickness ranges from about 50 Å to about 1,000 Å." Continuing at Page 6, lines 5 - 6: "The Ta layer deposited over the TaN_x layer has a desired thickness ranging from about 5Å to about 500 Å ." And, at Page 6, lines 14 - 17: "Since the crystal orientation of the copper is sensitive to deposition temperature, it is important that the maximum temperature of the copper either during deposition or during subsequent annealing processes not be higher than about 500 °C." The TaN_x layer thickness, Ta layer thickness, and substrate temperature during deposition of the conductive layer (and in subsequent processing steps) are the limitations present in Claim 8. Applicants show that a conductive (copper) layer applied over the combined barrier layer and wetting layer structure of Claim 8 will have an improved electromigration resistance.

Claim 9 (which depends from Claim 8) includes the limitation that the conductive layer is copper, the preferred conductive material illustrated in Figure 2 of the pending application. Claims 10 - 12 (which depend from 8), and Claims 14/8, 14/12, and 15 - 17 (which depend from Claim 8) include additional limitations which are preferred dependent embodiments of the subject matter claimed in Claim 8.

Clearly, the absence of any discussion of electromigration in the prior art references cited is an indication that the references do not address the problem addressed by applicants and do not address the subject matter which falls within the scope of the claim limitations of Claim 8 and claims which depend therefrom.

Re Group 2: Claims 13 and 14/13 pertain to a method where the structure is a contact via, so that the thickness requirements for the TaN_x layer and the Ta layer , while meeting the minimum thickness requirements of Claim 8, exhibit a maximum thickness which is less than that specified in Claim 8. The same arguments as those provided with reference to the Group 1 claims apply here.

Re Group 4: Claims 21 and 22 pertain to a method of producing a copper interconnect structure comprising a combined TaN_x /Ta barrier layer and wetting layer, and an overlying copper layer wherein the Cu <111> crystallographic content of the overlying copper layer is at least 70 % of the <111> crystallographic content which can be obtained by depositing the copper layer over a pure Ta barrier layer which is about 500 Å thick, and essentially include the limitations which are present in Claim 8 regarding layer thicknesses and copper processing temperatures. These claim limitations provide a method of forming a structure which provides the improved electromigration resistance, as previously described. The at least 70 % reference is based on data provided in Figure 2, which pertains to Cu <111> peak intensity and FWHM (an indicator of crystallographic

orientation). As previously described, crystallographic orientation is tied directly to electromigration behavior.

Clearly, the absence of any discussion of electromigration in the prior art references cited is material, since the subject matter of electromigration behavior falls within the scope of the claim limitations of Claims 21 and 22.

Re Group 6: Claim 27 pertains to a method of producing a copper-comprising contact structure comprising a combined TaN_x /Ta barrier layer and wetting layer, and an overlying copper layer having a <111> crystallographic content which is at least 70 % of the copper <111> crystallographic content which can be obtained by depositing the copper layer over a pure Ta barrier layer which is about 300 Å thick, and essentially includes the limitations of Claim 23 regarding layer thicknesses and copper layer processing temperatures. These claim limitations provide a method of forming a structure which provides the improved electromigration resistance, as previously described with reference to Claims 21 and 22.

Clearly, the absence of any discussion of electromigration in the prior art references cited is an indication that the references do not address the problem addressed by applicants and do not address the subject matter which falls within the scope of the claim limitations of Claim 27.

Further, it is well established that claims are read in the light of the disclosure of the specification on which they are based, not in a vacuum. *In re Dean*, 291 F.2d 947, 130 U.S.P.Q. 107,110 (C.C. P.A. 1961). "Patent claims must be read in view of the specification of which they are a part." "Claim

construction inquiry therefore, begins and ends in all cases with the actual words of the claim, the written description can provide guidance as to the meaning of the claims, thereby dictating the manner in which the claims are to be construed, even if the guidance is not provided in explicit definitional format". *Scimed Life Systems, Inc. v. Advanced Cadriovascular Systems, Inc.*, 58 U.S.P.Q.2D (BNA) 1059, (Fed.Cir., 2001).

The Second New Issue is also a general one:

WHICH LAYER IS THE FIRST LAYER AND WHICH LAYER IS THE SECOND LAYER ?

There is a significant amount of confusing discussion regarding the order of deposition of various layers in the Examiner's answer. The confusion lies in the direction from which layers are counted. In some instances, the first layer is the layer at the top of a stack of layers. In other instances, the first layer is the layer at the bottom of a stack of layers, because it is the first layer deposited on the underlying substrate. With regard to applicants' claimed invention, what is important is the particular layer which is in contact with the conductive layer. For example, in Claim 1, the first layer is TaN_x and the second layer is Ta <u>overlying</u> the first layer. Thus, when the conductive layer is deposited over this structure, it contacts the Ta layer.

In Claim 6, a copper layer is deposited <u>overlying</u> the barrier layer (overlying the second layer which is Ta).

In Claim 7, a copper contact via structure includes the barrier layer of TaN_x having an overlying layer of Ta, with a copper fill deposited over the barrier layer (over the Ta), where the copper fill has a Cu <111> crystallographic content which is at least 70 % of the crystallographic content which can be obtained using a pure Ta barrier layer which is 250 Å thick. As

explained in applicants "Summary Of The Invention", referenced above, tantalum nitride (TaN_x) is a better barrier layer for copper than tantalum (Ta). However, copper deposited directly over TaN_x does not exhibit a sufficiently high degree of <111> crystal orientation to provide the desired copper electromigration characteristics. A barrier layer structure comprising a layer of Ta overlying a layer of TaN_x provides both a barrier to the diffusion of a copper layer deposited thereover, and enables the formation of a copper layer having a high <111> crystallographic content, so that the copper electromigration resistance is increased.

The Board of Patent Appeals is respectfully requested to view all arguments in the context of which layer of material is <u>directly</u> underlying (in contact with) the copper layer, as it is this layer which most significantly affects the crystalline structure of the copper layer deposited thereover. (This assumes that the thickness of the material directly underlying the copper layer is adequate to permit formation of the dominant crystalline structure of the underlying material).

The Third New Issue:

WHETHER TITANIUM AND TANTALUM AND THEIR RESPECTIVE NITRIDES HAVE BEEN ESTABLISHED TO BE ART-RECOGNIZED EQUIVALENTS

The Examiner states in his Examiner's Answer at Page 7, lines 3 and 4, that titanium and tantalum and their respective nitrides have been established to be "art-recognized equivalents". Applicants would argue that this is not true, particularly in this instance. The importance of the crystal orientation of the underlying layer in contact with the copper layer in affecting the crystalline structure of a copper layer being deposited thereover is discussed above.

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U.S. Patent No. 5,882,399 to Ngan et al., contains specific embodiments showing the crystal orientation for a titanium (Ti) layer which is shown as having <002> crystallographic content ranging from about 80 % to 200 % (Figure 4).

Applicants, in order to obtain a high <111> content in a copper layer deposited over a barrier layer, teach that the copper should be deposited over a Ta layer rather than a TaN layer. As shown in Figure 2, when copper is deposited over a TaN layer, the peak intensity for <111> copper is only about 2,000; this contrasts with copper deposited over a Ta layer, where the <111> peak intensity for copper is about 30,200. This is because the <111> content of the Ta is high, while the <111> content of the TaN is low.

While the crystal orientation of the Ti layer described in U.S. Patent No. 5,882,399 is high in <002> orientation, the crystal orientation for the Ta layer described by applicants is high in <111> orientation. It is not true that tantalum and titanium are equivalents in terms of crystal orientation. Since crystal orientation is critical in applicants' invention, the Examiner's insistence in equating these two materials is misplaced.

This Reply To Examiner's Answer is submitted in triplicate.

Respectfully submitted,

Shirley L. Church

Shirley L. Church
Registration No. 31,858
Attorney for Applicants

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Correspondence Address:
Patent Counsel
Applied Materials, Inc.
P.O. Box 450-A
Santa Clara, California 95052